J. Trop. Agric. and Fd. Sc. 35(1)(2007): 71–79

Quality of papaya in modified atmosphere packages under simulated storage condition for export by sea

(Kualiti betik di dalam bungkusan atmosfera terubah suai dalam penyimpanan yang disimulasikan untuk eksport melalui kapal laut)

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Key words: modified atmosphere, package, simulated storage, quality, storage life, papaya

Abstract

Modified atmosphere packaging has been used for maintaining the quality of some fruits during transportation and distribution to market outlets. The technique was used in the present study to develop several modified atmosphere packages for Eksotika papaya. About 6 kg fruits were packed in each package treatments of polyethylene bag, impermeable container with aperture, polyethylene bag with aperture and control package (without modified atmosphere system). The fruits were stored at 12 °C for 5 weeks to simulate the condition and handling period required for export by sea to Europe.

The gas compositions were maintained between 2–6% O_2 and 8–9% CO_2 for polyethylene bag and polyethylene bag with aperture, while for the impermeable container with aperture, the composition was about 15% O_2 and 7% CO_2. The overall ethylene concentration in all packages was less than 1.0 ppm. The conditions in polyethylene bag and polyethylene bag with aperture were favourable to maintain the quality of Eksotika papaya up to 5 weeks storage at 12 °C. The weight loss of fruit in both packages was low, skin colour was maintained and the chilling injury and diseases were controlled during storage. All fruits ripened normally after being displayed for 3 days at ambient room.

Introduction

Fruits for long distant export markets could be transported using either air or sea freight. Air freight is commonly used by Malaysian exporters due to the short travelling period and simple handling technique. However, the cost of the freight is quite expensive. Sea freight has the advantages of delivering larger quantity produce and cheaper freight cost, but the storage life of produce should be extended to meet the longer shipping period. It was estimated that a storage life of about 4–5 weeks is needed for shipping Malaysian fruits to European markets (Mohd. Salleh and Ng 1988; Abd. Shukor et al. 1989).

A good packaging system facilitates handling as well as improves quality and the storage life of fresh produce in the market. One of the approaches for delivering fresh produce, especially to distant market, is the use of modified atmosphere packaging (MAP). This is done by packing fresh produce in a polymeric film to allow self-modification of atmosphere in the package. The packaging film with the ability to diffuse certain amounts of oxygen (O_2) and carbon dioxide (CO_2) into or from

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the package creates an atmosphere of low O_2 and high CO_2 concentrations desired by the fruit. Both low O_2 and high CO_2 concentrations reduce respiration rate, delay ripening and hence extend the storage life of fruits.

In Malaysia, this technique has been developed for several tropical fruits including banana, papaya, rambutan, guava and starfruit (Abdullah et al. 1992; Rohani et al. 1996; Mohd. Salleh et al. 1999). However, only works on banana has been evaluated successfully in commercial export shipments by sea from Malaysia to Hong Kong, Japan and Europe (Abdullah and Mohd. Salleh 1993).

The Eksotika papaya responded favourably to modified atmosphere (MA) package using low density polyethylene (LDPE) film, with the extension of storage life to double than for non-MAP fruits (Abd. Shukor et al. 1994). The fruits packed in LDPE bag were less sensitive to chilling injury when stored at 10 °C (Latifah et al. 1993).

Rohani et al. (1993) used the technique to pack about 6 kg Eksotika papaya as one of the packaging treatments in the shipment trials to the Middle East by sea. Although the overall quality of fruit packed in MAP was slightly better than non-MAP fruit, the storage life of fruit was only about 3–4 weeks. Weight loss, change in colour, chilling injury and disease infection still occurred although at a reduced level. The size of film used for the MAP may not be the optimum size required for creating the optimum atmospheric conditions for the fruit.

The performance of the MAP varies due to several factors such as initial fruit quality, maturity stage, rate of respiration, film permeability and handling condition. Most tropical fruits are highly respiring produce, which require a highly permeable film to allow more O_2 and CO_2 transmission across the film. The permeability of most available LDPE films is not permeable enough to create an optimum MA condition of 2–5% O_2 and 5–10% CO_2 needed for most tropical fruits (Kader et al. 1989). For papaya, the optimum atmospheric condition for storage is recommended between 2–5% and 5–8% respectively for O_2 and CO_2 (Yahia 1997).

Even the most permeable film such as polyvinyl chloride stretch-film, is still insufficiently permeable and may cause over-modification (Geeson 1990). Over-modified atmospheres is a situation where CO_2 concentration increases to more than 15%, while O_2 decreases to less than 2%, which may create an anaerobic respiration of the fruit leading to its deterioration (Kader et al. 1989; Geeson 1990).

Hence, the present study was undertaken to develop a more stable and precise MAP for Eksotika papaya. Emphasis was also given to incorporate a single tube aperture as an additional technique to achieve the desired gas composition, hence maintaining quality and extending storage life of the fruit. Verification was carried out under the simulated storage condition recommended for export by sea to Europe.

Materials and methods

Preparation of fruit

Eksotika papayas were harvested from a commercial farm at Bidor, Perak and transported to laboratory in Serdang, Selangor. Fruit at maturity stage 2 (skin colour green with traces of yellow), normal shape and good quality were selected for the study. Fruits were washed with chlorinated water to remove possible dirt, soil and foreign matter. The fruits were then treated with double hot water treatments by dipping the fruits in a tank of warm water at 42 °C for 30 min, followed by another tank with warm water at 49 °C for 20 min to control diseases and fruit flies (Sepiah et al. 1991).

After hot water dipping, the fruits were cooled with water at ambient temperature for 20 min before dipping in 250 ppm propiconazole solution for 5 min to control fungus. The fruits were allowed to dry properly before individually wrapped with

polystyrene net to protect from mechanical damage, particularly due to contact against each other in the package.

Package designs

Four types of packages were developed and evaluated in the study. The packages were LDPE bag (LDPE package), impermeable container with a single aperture (aperture package), LDPE bag with a single aperture (LDPE + aperture package) and package without wrap or bag as control treatment. The precise design for each package was predicted using computer program developed by Mohd. Salleh et al. (1999). The package was designed to pack an approximate total weight of about 6 kg Eksotika papaya placed in a commercial corrugated fibreboard box of 370 mm (L) x 300 mm (W) x 170 mm (H) commonly used for distribution to export markets (Mohd. Salleh et al. 1991; Rohani et al. 1993).

Nine fruits were arranged in each box and the exact net weight of the fruits in the package was measured. For the LDPE bag, the available film in the market with thickness of 0.04 mm was selected. A total surface area of the film to fit into the box was calculated at about 988,000 mm^2. For package with a single aperture, a silicon tube with 18 mm internal diameter and length of about 40 mm was placed in the opening of the LDPE bag, as well as into the top lid of the impermeable container. The opening of the LDPE bag was tied tightly with a rubber band, while the top lid of the impermeable container was closed and fixed tightly with cellophane tape. Each package treatment was replicated 4 times.

Simulated export condition

All fruits in the package were stored in a cold room set at temperature of 12 °C and relative humidity between 85–90%. These conditions were selected to follow recommendation by Rohani et al. (1993) for shipping Eksotika papaya in refrigerated container. Fruits were kept for 5 weeks to simulate the approximate shipping time needed from Malaysia to Europe (Mohd. Salleh and Ng 1988; Abd. Shukor et al. 1989).

Measurement of gas

The concentrations of O_2, CO_2 and ethylene in all packages were measured using a gas chromatograph (GC). The O_2 and CO_2 were measured using a Varian 1420 GC equipped with a thermal conductivity detector, while ethylene concentration was measured using a Varian 1400 GC equipped with a flame ionization detector. For each measurement, 1 ml of the headspace gas was withdrawn from each package using an air-tight hypodermic syringe and injected into particular stainless steel GC column. The measurements of these gases were initially taken daily at transient state, followed by weekly after a steady state concentration were achieved.

Analysis of quality

Quality of the fruit was analysed at the end of the storage period. Fruits were taken out from the cold room and the packages were opened. The net weight of the fruits after storage was measured and compared with the initial net weight to determine weight loss during storage. Physical quality of the fruits, which includes skin colour, chilling injury development, disease infection, appearance and acceptability was analysed using the following scales:

Skin colour (Rohani and Serrano 1994):

1. Full green
2. Green with trace of yellow
3. More green than yellow
4. More yellow than green
5. Yellow with trace of green
6. Fully yellow

Chilling injury and diseases (Rohani et al. 1997):

0. Not affected
1. Slightly affected
2. Moderately affected
3. Severely affected

Appearance and acceptability (Abdullah et al. 1993):

1. Very bad
2. Bad
3. Slightly bad
4. Neither good nor bad
5. Slightly good
6. Good
7. Very good

Fruits were allowed to ripen naturally at ambient with a temperature of about 25 °C. After the fruits had ripened (colour score 5–6), their skin colour, chilling injury, diseases, appearance and acceptability were evaluated using the above hedonic scales. Fruits were cut into two and evaluated for taste and pulp acceptability using a similar scale from 7 (very good) to 1 (very bad).

The biochemical qualities of the fruit, particularly pH and percentage of total soluble solid (TSS) were also analysed. The pH was determined by blending half of the pulp and measuring with an Orion digital pH meter model SA520. The TSS of the pulp's juice was measured using an Atago digital refractometer model PR-1 (0–32% Brix).

The data were statistically analysed with analysis of variance and the Duncan Multiple Range Test was used as the test of significance. This statistical analysis was carried out to rectify the data, particularly the subjective quality assessments conducted in the study.

Results and discussion

Gas composition in MA packages

The performance of MAP designs for fresh produce is directly associated with the ability of the package to convert the composition of respiratory gases into its optimum composition in the shortest time possible and maintain the composition throughout the storage period.

The result showed that all MA packages in the present study were able to decrease O_2 and increase CO_2 concentrations as compared with 20.9% O_2 and 0.03% CO_2 in control package *(Figure 1).* For the LDPE bag (LDPE package), the O_2 concentration declined to about 3.0%, while CO_2 concentration rose to about 9.3% after about 3 days in storage. These steady state or equilibrium concentrations were maintained for about 3 weeks before further changing in the 4th and 5th weeks of the storage period, where the O_2 decreased to about 2% and CO_2 rose to about 12%. Although

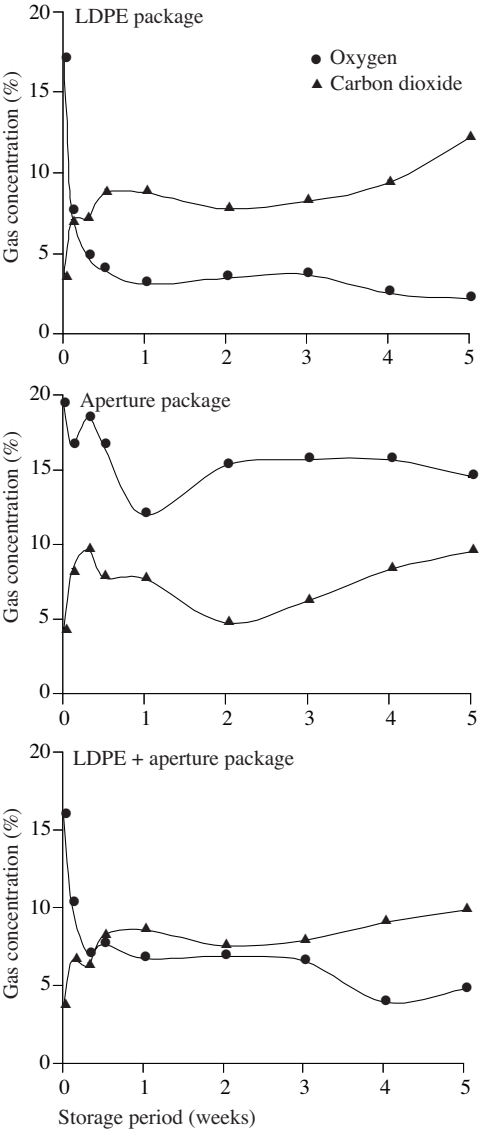

Figure 1. Oxygen and carbon dioxide concentrations inside MA packages kept at 12 °C (mean of 4 replicates)

the O_2 concentration was within the 2–5% recommended concentration for tropical fruit, the CO_2 concentration was above the 10% limit, which may cause severe CO_2 injury to the fruit (Kader et al. 1989).

Similar trend was also observed in the impermeable container equipped with aperture (aperture package) *(Figure 1)*. The use of aperture restricted the level of CO_2 concentration in the package to less than 10% limit of injury. The O_2 concentration however, declined to only about 15% due to the transmission of the gas across only through the aperture. Further improvement on the development of MA system was observed when the aperture was incorporated into the LDPE bag (LDPE + aperture package). The O_2 concentration further declined to about 6%, while CO_2 concentration maintained at about 7–8%.

The optimum combination of low O_2 and high CO_2 composition is an important parameter in extending storage life of fresh produce. The low O_2 decreased the respiration rate of produce, while high CO_2 benefited as a fungicidal treatment to the produce (Talasila et al. 1992). However, very low O_2 may cause anaerobic respiration, which can accelerate senescence and spoilage of the produce (Church and Parsons 1995), while the atmosphere containing more than 10% CO_2 may cause physiological disorder or CO_2 injury to the fruit (Kader et al. 1989).

In the present study, the LDPE bag with aperture (LDPE + aperture package) was found to be the most suitable package for precise MA system. The steady state or equilibrium O_2:CO_2 composition developed in the package was about 5.9%:8.6% as compared with 3.0%:9.3%, 14.7%:7.3% and 20.9%:0.03% for LDPE bag (LDPE package), impermeable container with aperture (aperture package) and control package respectively *(Table 1)*. The atmospheric composition developed by the LDPE bag with aperture (LDPE + aperture package) was within the optimum composition of 2–5% O_2 and 5–10% CO_2 required for extending the storage life of most tropical fruit, including papaya (Kader et al. 1989). The additional gas transmission using a single aperture introduced into the LDPE bag is capable of modifying the atmosphere in the package more precisely within the safe limits to avoid fruit deterioration during storage.

Ethylene concentration in the package should be minimised to ensure no ripening process occur during storage. The result showed that the concentration of ethylene in all MA packages was initially below 0.5 ppm, but increased slightly after three weeks in storage to about 1.0 ppm at the end of the 5-week storage *(Figure 2)*. The slight accumulation of ethylene gas in the package indicated that the ripening process had been initiated by the end of the five-week storage. However, the overall ethylene

Table 1. Mean steady-state oxygen, carbon dioxide and ethylene concentrations in papaya packages

Package	Oxygen (%)	Carbon dioxide (%)	Ethylene (ppm)
LDPE	3.02a	9.29a	0.61b
Aperture	14.67c	7.33b	0.64b
LDPE + aperture	5.85b	8.62ab	0.55b
Control	20.90d	0.03c	0.00a

Mean values in the same column with the same letters are not significantly different (p <0.05)

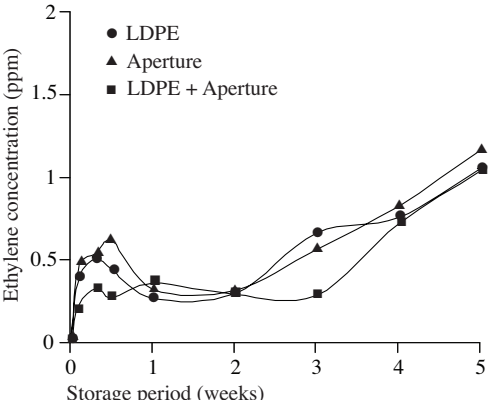

Figure 2. Ethylene concentration inside all packages stored at 12 °C (mean of 4 replicates)

concentrations in all MA packages were still very low (below 1.0 ppm) to seriously induce the ripening process of the fruit *(Table 1)*. Moreover, the use of ethylene absorbent by Rohani et al. (1997) was only able to decrease about 70% of ethylene gas accumulated in the papaya package.

Quality of fruits after storage

The quality of fruits was evaluated immediately after removal from cold storage. The result showed that there was no significant difference (p <0.05) in weight loss of fruit in all MA packages *(Table 2)*. The overall weight loss was less than 0.5%, which was half of the result reported by Rohani et al. (1997), when they recorded about 1% weight loss on papaya packed in MAP stored at 10 °C for more than 5 weeks.

There was a tendency that MA packages using LDPE film were highly effective in preventing weight loss due to the barrier of the film to vapour transmission, which form moisture-saturated air in the package (Abdullah et al. 1992). Very humid condition however, may cause moisture condensation on the surface of the LDPE film, which adversely affect the permeability of the film resulting in an unfavourable MA composition (Day 1994). The relative humidity between 85–90% was essential to avoid condensation, while preventing the fruit from wilting and shrivelling.

The simulated export condition used in the present study was highly acceptable in maintaining skin colour, as well as preventing the fruit from chilling injury and diseases *(Table 2)*. Skin colour of papaya in all packages (including control) turned to the level above colour stage 3 (more green than yellow) as compared with the initial colour stage 2 (green with trace of yellow) at the beginning of the experiment. The change in colour is a natural process since the fruits still continue their living processes even under low O_2 and high CO_2 composition (Kader et al. 1989). This colour stage is still acceptable by buyers at the point of entry in the importing countries (Rohani et al. 1993).

The minimum occurrence of chilling injury and diseases on papaya in all packages (including control) indicates that the simulated storage condition is appropriate to keep the fruit up to 5 weeks. Furthermore, the LDPE bag with aperture (LDPE + aperture package) provided even better protection to the fruit against chilling injury and diseases.

Fruit appearance and acceptability were still above slightly good (level 5) for fruits in LDPE bag (LDPE package) and LDPE bag with aperture (LDPE + aperture package). The quality of fruits from other packages (aperture package and control package) was almost unacceptable for distribution to retail market. Since the appearance and overall acceptability are regarded as the main quality measures by consumers in the market, the result suggested that the precise MA packages were able to maintain the quality of Eksotika papaya for up to 5 weeks. This storage period was sufficient for the transportation of the fruit to European markets by sea shipment.

Table 2. Overall quality of fruit upon removal after 5 weeks storage at 12 °C

Package	Weight loss (%)	Skin colour	Chilling injury	Disease	Appearance	Overall acceptability
LDPE	0.16a	3.75b	0.25a	0.75ab	5.00ab	6.25a
Aperture	0.48ab	3.00a	0.50a	1.50b	4.75b	4.25b
LDPE + aperture	0.35ab	3.25ab	0.00a	0.25a	6.00a	6.75a
Control	0.79b	3.75b	0.75a	0.75ab	4.25b	4.00b

Mean values in the same column with the same letters are not significantly different (p <0.05)

Quality of fruit after ripening

Fruits were fully ripened after exposure at ambient temperature (25 °C) for 3 days, where skin colour turned to stage 6 (fully yellow) *(Table 3)*. Chilling injury and diseases on the ripened fruit were recorded low (below scale 1 or slightly affected), especially for fruit in LDPE bag (LDPE package) and LDPE bag with aperture (LDPE + aperture package). For the appearance, fruit in LDPE bag (LDPE package) and LDPE bag with aperture (LDPE + aperture package) showed a significantly higher score (p <0.05) as compared with fruit in impermeable container with aperture (aperture package) and control. Fruit in LDPE bag with aperture (LDPE + aperture package), however, was slightly better (above 6.0 or good), as compared with fruit in LDPE bag (LDPE package).

It was more significant in overall acceptability (p <0.05), where the fruit in LDPE bag with aperture (LDPE + aperture package) obtained the highest score (5.75 or close to good) as compared with fruit in other packages, including LDPE bag (LDPE package). Fruit with overall acceptability above 5 (slightly good) was classified as highly acceptable for fresh consumption.

Fruit packed in LDPE bags, either with or without aperture had significantly higher eating quality or taste (p <0.05) as compared with fruit from impermeable container with aperture (aperture package) and control packages *(Table 4)*. The pulp of fruit taken from the LDPE bag with aperture (LDPE + aperture package), however, was highly acceptable (p <0.05) as compared with fruit from other packages. Analysis on pH and total soluble solid (TSS) of the fruit, however, found no significant differences (p <0.05) among fruit from all packages, except control package. The measured pH was about 5.0, while TSS was about 11%, similar to the values reported by Rohani et al. (1997).

Conclusion

Precise MA packages developed in the present study were able to alter gas composition in the package. The LDPE bag (LDPE package) was able to reduce O_2 concentration to the level favourable for Eksotika papaya. However, CO_2 concentration in the package rose to more than 10% limit which may cause

Table 3. Physical quality and acceptability of fruit after ripening

Package	Skin colour	Chilling injury	Disease	Appearance acceptability	Overall
LDPE	6.00a	0.75a	1.00ab	5.50a	4.75b
Aperture	6.00a	1.00a	1.75bc	4.25b	4.25b
LDPE + aperture	6.00a	0.25a	0.50a	6.25a	5.75a
Control	6.00a	1.00a	2.50c	4.00b	3.75b

Mean values in the same column with the same letters are not significantly different (p <0.05)

Table 4. Chemical content and eating quality of fruit after ripening

Package	Taste	Acceptability	pH	TSS
LDPE	4.50ab	4.00b	4.96ab	11.08ab
Aperture	3.00b	2.50c	4.76b	10.63b
LDPE + aperture	6.00a	5.75a	5.13a	11.70a
Control	3.25b	3.25bc	4.97ab	9.65c

Mean values in the same column with the same letters are not significantly different (p <0.05)

physiological injury to the fruit. The use of aperture made from a silicon tube showed a significant improvement in the level of gases concentrations in MA package, especially the level of CO_2. The LDPE bag inserted with a single aperture (LDPE + aperture package) was found more efficient in developing the MA composition suitable for the fruit. The O_2 and CO_2 concentrations were about 6% and 9% respectively, closed to the optimum level of 2–5% O_2 and 5–10% CO_2 required for extending the storage life of most tropical fruit, including papaya.

Analysis of quality immediately after removal from the 5-week storage showed an acceptable fruit quality in all MA packages, especially for the fruit in LDPE bag (LDPE package) and LDPE bag with aperture (LDPE + aperture package). Similar results were also recorded on quality and chemical content of the fruit after ripening, with the fruit from LDPE bag with aperture (LDPE + aperture package) achieved the highest quality scores. An aperture attached to the LDPE bag had improved the transmission of respiratory gases, avoided over modification and ensured a reliable gas composition limits to avoid fruit deterioration. The package was able to maintain the quality of Eksotika papaya during the 5 weeks simulation study at 12 °C. The 5-week storage period was sufficient for exporting the fruit to Europe by sea.

Acknowledgement

The authors acknowledge Mr Abdullah Hassan, Ms Norhayati Maning, Mr Jabir Husin and Mr Ismail Mustam for their assistance in conducting the study.

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Abstrak

Pembungkusan atmosfera terubah suai telah digunakan untuk mengekalkan kualiti buah-buahan semasa pengangkutan dan pengagihan ke destinasi pasaran. Teknik tersebut telah digunakan dalam kajian ini untuk mewujudkan beberapa bungkusan atmosfera terubah suai bagi betik Eksotika. Kira-kira 6 kg buah telah dibungkus di dalam setiap perlakuan bungkusan yang terdiri daripada beg polietilena, bekas tak telap udara dengan bukaan kecil, beg polietilena dengan bukaan kecil dan bungkusan kawalan (tanpa sistem atmosfera terubah suai). Buah tersebut disimpan pada suhu 12 °C selama 5 minggu untuk mensimulasi keadaan dan tempoh pengendalian yang dikehendaki bagi pengeksportan melalui kapal laut ke Eropah.

Komposisi gas dapat dikekalkan sekitar 2–6% O_2 dan 8–9% CO_2 untuk beg polietilena dan beg polietilena dengan bukaan kecil, manakala bagi bekas tak telap udara dengan bukaan kecil, komposisi gas adalah kira-kira 15% O_2 dan 7% CO_2. Kepekatan etilena keseluruhan di dalam semua bungkusan adalah kurang daripada 1.0 bsj. Keadaan di dalam beg polietilena dan beg polietilena dengan bukaan kecil tersebut adalah sesuai untuk mengekalkan kualiti betik Eksotika sehingga 5 minggu pada suhu 12 °C. Kehilangan berat bagi buah dari kedua-dua bungkusan adalah rendah, warna kulit dapat dikekalkan dan kecederaan suhu dingin dan penyakit dapat dikawal semasa penyimpanan. Semua buah masak secara normal setelah dibiarkan di bilik ambien selama 3 hari.

Accepted for publication on 23 May 2006